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STATUS OF THE WESTERN BUDWORM, CHORISTONEURA CARNANA CALIFORNICA, ON THE WEAVERVILLE RANGER DISTRICT, SHASTA-TRINITY NATIONAL FOREST - 1983

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ABSTRACT

The western budworm, Choristoneura carnana californica Powell, caused defoliation of Douglas-firs in 1983 on 93,000 acres of mixed ownership within the boundaries of the Weaverville District, Shasta-Trinity National Forests. Egg mass counts were markedly down from 1982 and fell below the levels estimated for 1981. Egg mass ratios, new to old and new to new, indicated an insect population that has declined, but remains in the outbreak phase over most of the infested acreage. Ratios in the northern part of the infestation indicated an increasing population. Growth reduction occurred in some trees, but the impact on merchantible trees has been negligible. Watershed, viewshed, recreational quality, and wildlife values have not been affected thus far. Egg mass densities and host type distribution indicated an infested area of 135,000 acres of light and moderate defoliation in 1984. Management alternatives and considerations for the area are briefly discussed, along with the life history of the insect and characteristics of the infested area.

INTRODUCTION

In early June, 1982, a detection report from the Weaverville Ranger District indicated that Douglas-firs along Bowerman Ridge and east of Trinity (Clair Engle) Lake were being defoliated by a budworm. Collections and rearings proved that the insect involved was Choristoneura carnana californica Powell, a red- and white-colored moth similar to certain forms described for the western spruce budworm, C. occidentalis

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Freeman. Aerial and ground surveys defined an infestation of approximately 33,000 acres, 5,500 of which were classified as heavily defoliated (Dale 1983, Fig. 1). Egg mass densities indicated an intensification of defoliation in 1983.

The consensus of the land managers of the various ownerships involved was to monitor the insect population and the effects of defoliation on the host type through 1983. This decision was based largely upon the lack of a precedent that would indicate potential longevity of the infestation in Trinity and Shasta Counties. Also, at the end of 1982 there was no demonstrable permanent damage in any of the stands infested. The results of the monitoring and evaluation of the insect population and its host by the Forest Service, the various landowner-cooperators and the California Department of Forestry form the basis of this report.

The Insect - *Choristoneura carnana californica*[1/]

This budworm has been collected in the Coast Range of California as far south as Santa Cruz County. It also has been taken from Douglas-firs in Lake and Napa Counties and along the southern Cascade Range and the Sierran west slope as far south as El Dorado County (Powell 1980). The adult moths are brick red and heavily marked on the forewing. Markings vary from distinct to mottled bands. Wing spans range from 19 to 25 mm.

The life cycle of this budworm at Trinity Lake is not exactly known. However, as presently understood, the moths emerge from the pupal stage from mid-June through early July, and almost all die before the last week of July (Fig. 2). During this period, light green eggs are laid in masses on the underside of needles. Within a short time the larvae develop and hatch from the eggs. The newly hatched larvae do not feed, but instead seek protection among lichens and bark scales, where they remain in silken shelters from July to late March of the following year.

When weather conditions become suitable in the spring, the larvae mine into developing male and female flowers. When this preferable food source is scarce, they mine into old needles until the vegetative buds begin to swell. It is thought that young larvae do not develop rapidly on older needles and the survival rates decline when this food source must be utilized. Larvae prefer to feed upon new foliage throughout the spring. However, older needles are eaten by later larval stages if the population strips the new foliage. Larvae develop rapidly, and population suppression measures, if applied, would take place in late May or early June (Fig. 2).

1/ There is no authorized common name for *Choristoneura carnana californica*. The name western spruce budworm for *C. occidentalis* presently is being reevaluated because "spruce" is not descriptive of the insect in the western United States. Therefore, "western budworm" is used in a general sense, not as an accepted common name.

Figure 1. Trinity Lake western budworm infestation, Weaverville District, Shasta-Trinity National Forests, 1982. Shaded areas, aerially observed defoliation. L = light, L/M = light and moderate, and H = heavy defoliation. ::::::: Boundary, National Recreation Area.

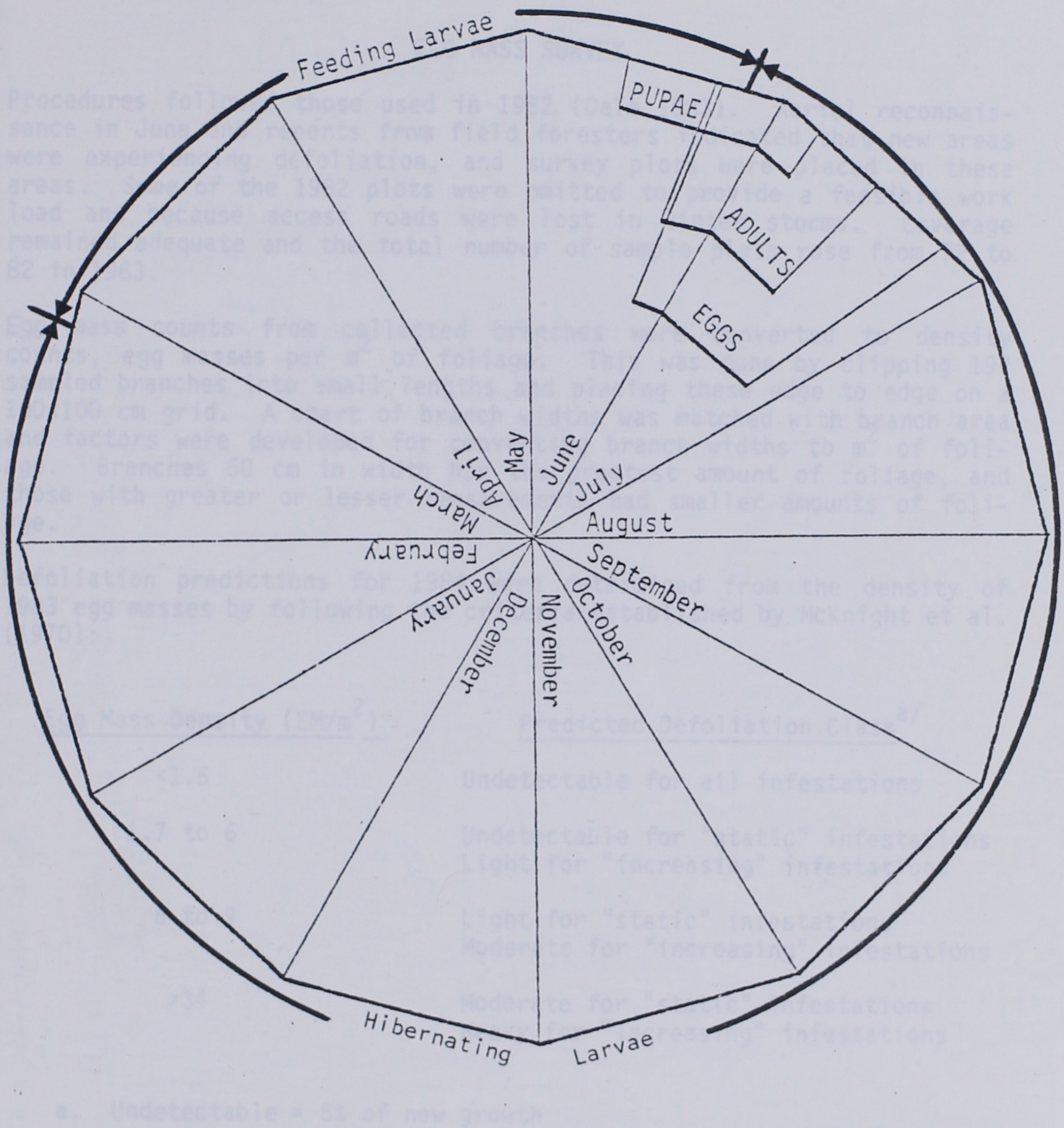


Figure 2. General representation of the seasonal occurrance of the budworm, Choristoneura carnana californica Powell, in the vicinity of Clair Engle (Trinity) Lake, Trinity and Shasta Counties, California.

During June the larvae transform to light brown pupae, about 13 mm long. Pupae are found hanging from branchlets, often in association with the light silk webbings of the larvae. The pupal stage is of short duration.

EGG MASS SURVEY

Procedures followed those used in 1982 (Dale 1983). Aerial reconnaissance in June and reports from field foresters indicated that new areas were experiencing defoliation, and survey plots were placed in these areas. Some of the 1982 plots were omitted to provide a feasible work load and because access roads were lost in winter storms. Coverage remained adequate and the total number of sample plots rose from 72 to 82 in 1983.

Egg mass counts from collected branches were converted to density counts, egg masses per m^2 of foliage. This was done by clipping 197 sampled branches into small lengths and placing these edge to edge on a 100x100 cm grid. A chart of branch widths was matched with branch area and factors were developed for converting branch widths to m^2 of foliage. Branches 60 cm in width had the greatest amount of foliage, and those with greater or lesser measurements had smaller amounts of foliage.

Defoliation predictions for 1984 were determined from the density of 1983 egg masses by following the criteria established by McKnight et al. (1970):

Egg Mass Density (EM/m^2)	Predicted Defoliation Class[a/]
<1.5	Undetectable for all infestations
1.7 to 6	Undetectable for "static" infestations Light for "increasing" infestations
6 to 9	Light for "static" infestations Moderate for "increasing" infestations
>34	Moderate for "static" infestations Heavy for "increasing" infestations

a. Undetectable = 5% of new growth
   Light = 5 to 35% of new growth
   Moderate = 35 to 65% of new growth
   Heavy = 65% of new growth

Figure 3. Trinity Lake western budworm infestation. Weaverville District, Shasta-Trinity National Forests, 1983. VL = very light, L = light, L/M = light to moderate, M = moderate, H = heavy defoliation. //// Boundary, National Recreation Area.

RESULTS

Description of Areas Infested

The new areas infested generally fit the previous description (Dale 1983). However, the elevation of infested host type has now decreased to 2,000 ft. Several additional drainages are involved (Fig. 3). North-facing slopes and ridge tops remain the areas most heavily infested although more Douglas-firs on south-facing slopes are now involved.

Egg Mass Survey

The infestation now encompasses about 93,000 acres (Fig. 3), 77,000 acres of host type. Estimates on heavy, moderate, and light defoliation classes are 73%, 4%, and 23% of the acreage, respectively. New areas have appeared (Figs. 1 and 3) and some older ones have coalesced.

The average number of eggs per mass was somewhat lower in 1983 (Table 1). The number of eggs per mass for 1981 is currently considered an underestimate created by the difficulty in counting the number of eggs in partially collapsed masses that were one-year-old when counted in 1982. It is impossible to accurately count the number of eggs in totally collapsed masses.

Table 1. Number of eggs per egg mass at the Trinity Lake western budworm infestation, 1981-1983.

	No. Eggs/Egg Mass		
	1981	1982	1983
$\bar{x}$	26 ± 3.8[b/]	45[a/] ± 3.9	37 ± 2.6
Range	8-62	15-91	10-81

a/ Corrected from report 83-1.
b/ Standard error.

The ratio of new egg masses, 1983:1982, was in the range of 0.1:1 to 0.5:1 for the areas sampled in these years (Table 2). These ratios indicate a population decline as do the trends of the new to old ratios. The overall ratio for the latter was 0.9:1. This is much less than the 2.8:1 of 1982 and is a further indicator of population decline.

Classified by areas, the 0.4:1 of the Trinity Mountain Guard Station is significant, for this area includes many of the stands first defoliated and much of the severest defoliation. The older infestations on the east side of Clear Creek are also now less than 1:1 (0.7:1). Areas where the populations are increasing are Squirrel Flat-Cedar Creek-Halls Gulch, and Swift Creek-Coffee Creek (Table 2). The new areas of Wild Cow Mountain and Keno were expected to have a ratio similar to the overall ratio of 1982. That these new areas have not reached the ratios of those in nearby locations within a similar time-frame may indicate that the influences that have historically kept this insect at endemic levels may be reasserting themselves.

Large numbers of egg masses were sampled from many of the plots in 1982. This was not the case in 1983 (Fig. 4). No plot sample averaged more than 22 egg masses per m^2 of foliage in 1983, while 44 of 72 plots had counts of 22 or more in 1982, and 30 had counts of 34+ (a prediction of heavy defoliation). Whereas the histogram of egg masses per m^2 per plot in 1982 was broadly defined, the charting of 1983 samples follows a J-shaped pattern. This is not the result of additional plots in lightly infested areas, because the same form is followed when only plots sampled in both years are graphed along with new 1983 plots from heavily defoliated areas (Fig. 5). Both reflect the significantly lower average number of egg masses per m^2 in 1983.

The number of egg masses per m^2 of foliage decreased dramatically in 1983 -- 10 in 1981, 29 in 1982, and 7 in 1983. The 1981 figure is an underestimate because the counts were made in 1982 and egg masses are displaced from needles over time. Such is the character of attempts to reconstruct prior events. However, the trends of new to old egg mass ratios may still be useful if one assumes the rates of displacement as constant (Table 2).

Mapping of egg mass numbers indicates that the infestation in 1984 will approximate the levels shown in Figure 6. In spite of the increased area, about 135,000 acres (120,000 host type), the most notable feature is the absence of a prediction of heavy defoliation. Comparing numbers of egg masses in 1981 and 1982 to maps of the 1982 and 1983 infestations indicates that the prediction for 1984 is reasonable.

Table 2. Trinity Lake western budworm infestation, 1983 egg mass ratios and comparison with 1982

Area Infested		Egg Masses (No.)/M^2 Foliage		
		Ratio - New:Old		Ratio - New:New
		1983	1982	1983:1982
Clear Creek, east side	1	0.7:1	2.7:1	0.5:1
New area - Wild Cow Mtn.		1.4:1		
Trinity Mtn. Guard Station - main area	2	0.4:1	2.6:1	0.1:1
Bowerman Ridge + Norwegian Ranch	3	1.1:1	4.4:1	0.4:1
Blue Mtn & Nelson Gap	4	1.1:1	4.3:1[a/]	0.3:1[a/]
Squirrel Flat, Cedar Creek and Halls Gulch	5	1.4:1	(2.8:1)[b/]	
Swift Creek to Coffee Creek	6	3.7:1	(2.8:1)	
West side of lake - Hayward Flat and Mule Creek	7	1.1:1[c/]	(2.8:1)	
New southern area, Keno to the powerline	8	0.7:1	(2.8:1)	
SUMMARY		0.9:1	2.8:1[d/]	

a. Plots 52-55 only.
b. () = overall 1982 ratio, for comparison.
c. Low numbers of egg masses indicate a light infestation in 1984.
d. This ratio is the same as that of 1982; thus, the omission of some 1982 plots in 1983 was not a biased selection.

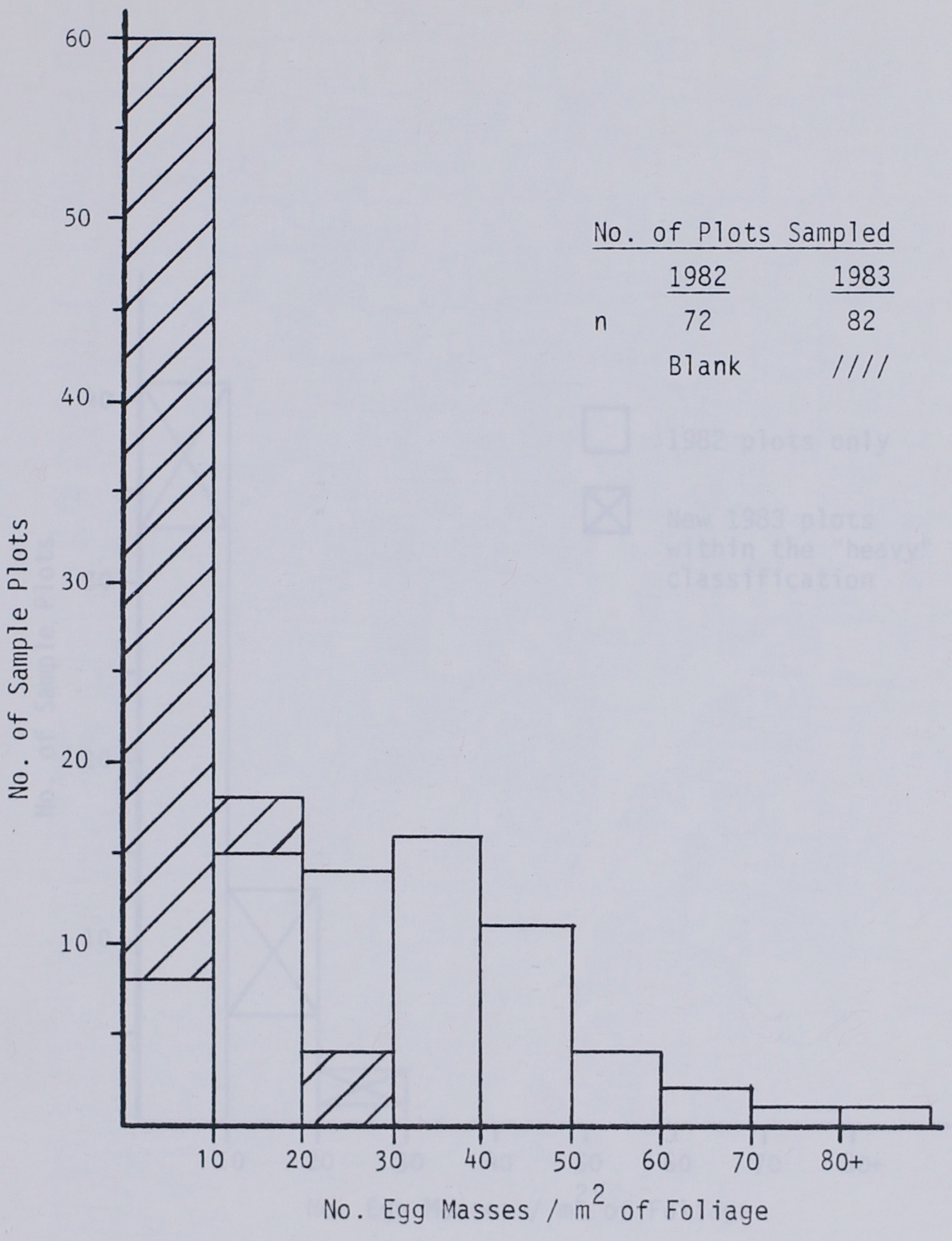


Figure 4. Frequency of sample plots by egg mass counts. Average number of egg masses per m^2 of foliage: 1981 = 10, 1982 = 29, 1983 = 7.

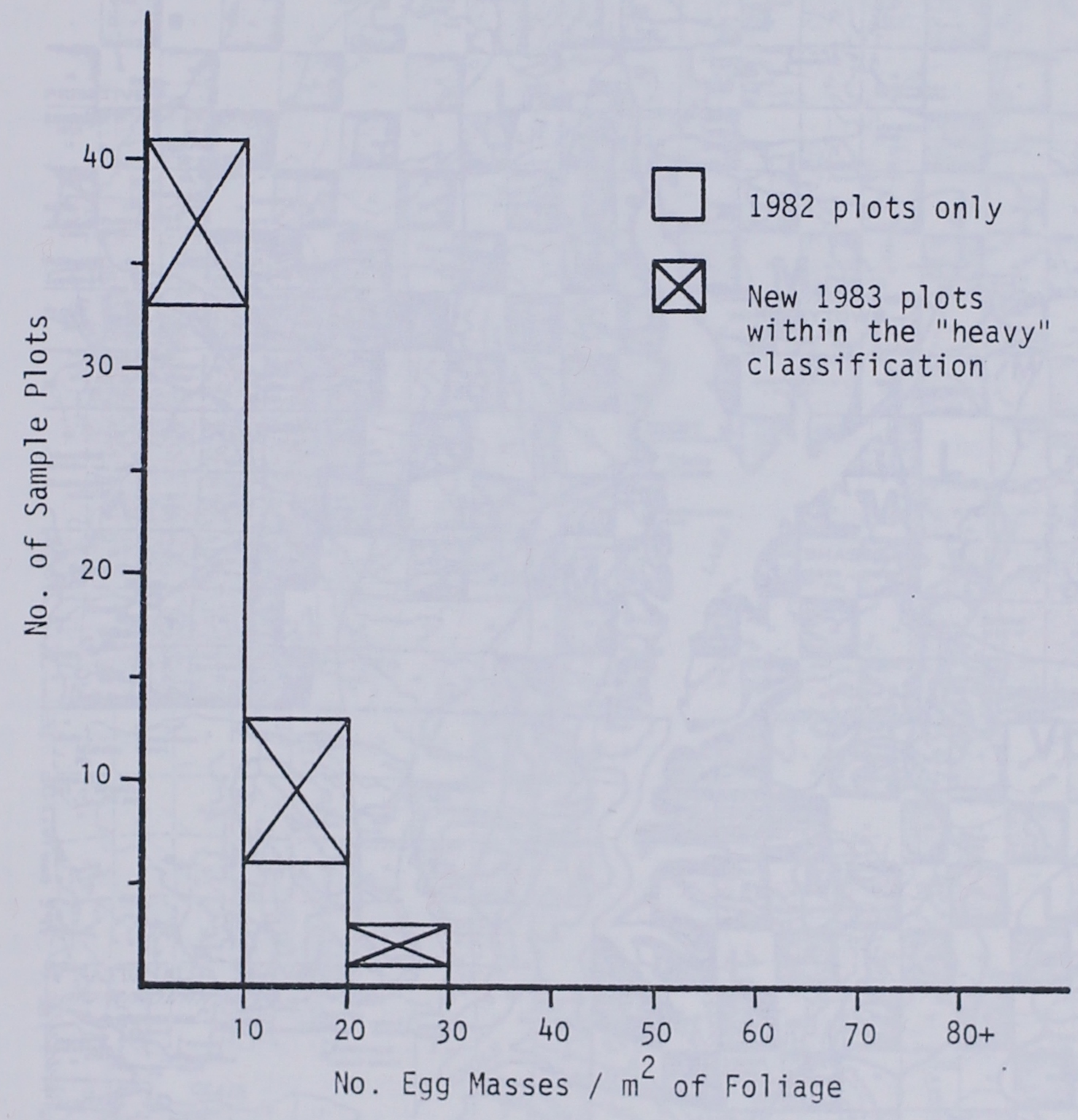
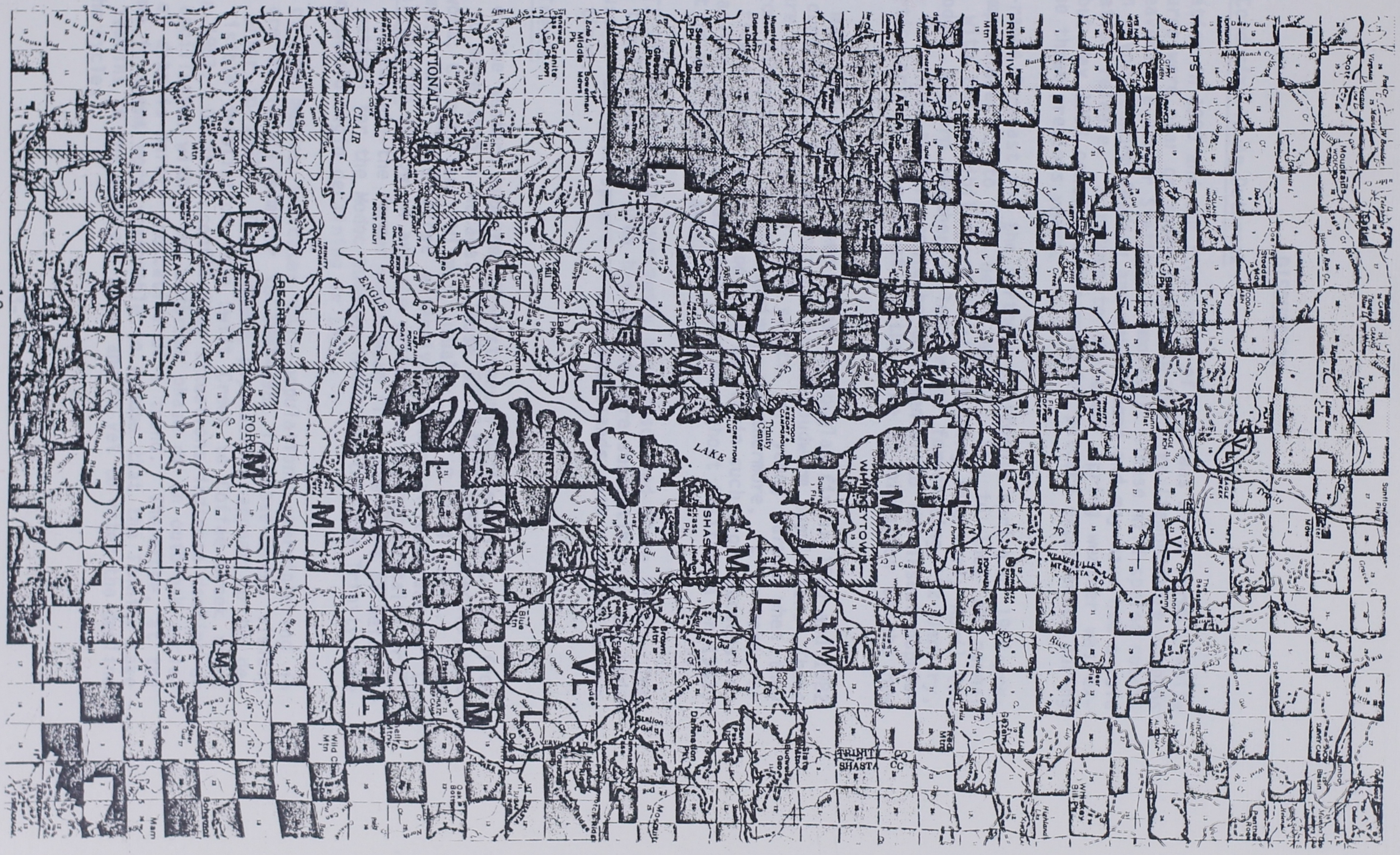


Figure 5. Frequency of sample plots by egg mass counts -- 1982 plots resampled in 1983 and new 1983 plots within areas where the Douglas-firs were heavily defoliated.

Figure 6. Predicted defoliation for 1984, Trinity Lake western budworm infestation, Weaverville District, Shasta-Trinity National Forests. //// Boundary, National Recreation Area. VL = very light, L = light, L/M = light to moderate, M = moderate, H = heavy defoliation.



DISCUSSION

Factors Conducive To An Outbreak

Precipitation in 1980 and the first half of 1981 was below normal, while temperatures were near or above normal in the area (temperature records at the Weaverville Ranger Station incomplete). These mild spring conditions can favor budworm feeding and development and may have had a role in population release. A return to the usual spring weather was expected, but May 1983 continued the warm-dry pattern experienced during May of the three previous years.

One long-range forecast for the northern California spring of 1984 predicts temperatures 2 to 3°F below normal, 140 to 150% of normal rainfall, with the possibility of frost extending into early April (J. Marvin Dodge, Western Weather - long range forecasting, 12 January, 1984. p. 6). This pattern could be detrimental to the insect population, particularly a late frost at the time of migration to the new foliage.

The heavy male and female flower crops on Douglas-fir in 1980 and 1982 may have contributed to the increase in the budworm population. These flowers are a very favorable food source for young larvae when they emerge from hibernation in the spring. Furthermore, it is rare for excellent flower crops to occur on Douglas-fir in such close succession. The Douglas-fir cone crop was very poor throughout California in 1983, and absent in the infested area.

The history of the area has previously been described (Dale 1983). The forest in the Trinity Lake area has become more susceptible to the budworm because of the development of numerous stands with canopies of two and three tiers.

Egg Mass Trends

Outbreaks of the western budworm, Choristoneura occidentalis, last from two years to more than a decade. Those of a California species, the Modoc budworm, C. retiniana (Wlsm.), usually last 3 to 4 years. Thus the dilemma: will this first extensive historical outbreak of C. carnana californica follow an average pattern for C. occidentalis or C. retiniana? To emulate the former would mean five more years of defoliation. The pattern for the Modoc budworm indicates that the Trinity Lake infestation should begin declining in 1984.

Abundance of egg masses indicates that populations overwintering in 1983-1984 are at levels similar to 1981-1982 in those areas visibly defoliated prior to 1983. Thus, these populations appear to be declining. Visible defoliation from Swift Creek to Coffee Creek first appeared in 1983. Do these conflicting situations indicate decline or merely an oscillation within the outbreak phase of an outbreak cycle? Two years of data is hardly indicative of a trend. Therefore, at the present time it seems more reasonable to assume that the Trinity Lake population remains in the outbreak phase and is yet to enter the decline phase of the cycle.

Status of the Host

Damage to defoliated trees is variable. Some Douglas-firs have been seriously defoliated. These are usually in the smaller size classes and 1/3 of the crown may have been severely defoliated. Suppressed and very small roadside trees are frequently 2/3 to 3/4 defoliated in the most severe areas. Tree mortality has not appeared and is not expected in 1984. Some terminal mortality has occurred down to a stem diameter of 1/4 to 3/8 inch. Bud set appears to be normal or near normal on many Douglas-firs in spite of defoliation. However, small trees in the older infested areas frequently have adventious buds for the majority of foliage production in 1984. Growth reduction has appeared in some trees, but the impact on merchantible trees (>12" dbh) is thus far negligible -- 7 bd ft per acre (survey, Southern Pacific Land Co.).

It is possible that growth reduction in some trees may be compensated by increased growth in adjacent trees. Not uncommon are Douglas-firs that have been only lightly defoliated in spite of the presence of nearby trees with moderate or heavy defoliation. Biochemical characteristics of the foliage, bud break in the spring, or harvesting of larvae by predaceous ants are but three possible reasons.

MANAGEMENT ALTERNATIVES

A. Maintain Current Management - No Action. The infestation will continue unless budworm mortality during the winter and spring of 1984 is heavy. Mortality of trees is not expected in 1984. However, dieback of terminals should become more common and growth loss in heavily damaged trees will continue. Impact in stands will not be as great as in individual trees. Decline in the insect population may or may not continue, but more acres will be classified as infested. The increase in acreage of 2.5 times for 1982 to 1983 is not expected for 1983 to 1984. Additional infested areas probably would result in 135,000 acres of infestation. Monitoring of damage and the insect population will continue in 1984.

B. Application of Chemicals or Microbials. Any treatment of the infestation would allow trees in the older areas to recover their vigor and prevent further terminal dieback. It would not guarantee against resurgence of the population or development of an infestation in the Douglas-fir type at risk in the area -- 185,000 acres within 240,000 total acres. The uniqueness of this infestation indicates that resurgence would not be as likely as in other western areas of North America. However, it must be recognized that changing characteristics of the Trinity forest during the 20th century (Dale, 1983) may have created conditions conducive to periodic outbreaks of the western budworm.

The insect population from Swift Creek to Coffee Creek is increasing much the same as 1982 populations were increasing. Treatment in this area where damage is just beginning would prevent growth loss and

dieback. Withholding treatment is also feasible, for the trees are not as heavily defoliated at this stage of the infestation as were the trees at Trinity Mountain Guard Station and Bowerman Ridge at a similar stage.

1. Aerial Application of Chemical Insecticides. A carefully timed and applied aerial application of a chemical insecticide will protect foliage from excessive defoliation and thus reduce damage. Results from suppression projects in other regions indicate more than one application may be required to achieve protection during an outbreak period.

Insecticides registered for use against the western budworm are:

a) Carbaryl (a carbamate insecticide). The Sevin-4-oil^{R} formulation of carbaryl has given consistently satisfactory results when properly applied and is the insecticide most commonly used against budworm infestations in western North America. Fairly broad-spectrum and relatively nonpersistent, it is only moderately toxic to warm-blooded animals and presents little hazard to mammals and birds when used at the registered rate. In contrast, carbaryl is toxic to fish, aquatic insects, and wild and domestic insect pollinators. No lasting unacceptable adverse environmental effects have been identified at the registered dosage rate.

b) Acephate$_{R}$ (an organophosphate insecticide formulated and marketed as Orthene^{R} - 75 or 95%). Acephate is a broad-spectrum insecticide of moderate persistance. Residues degrade fairly rapidly (4 to 15 days) and are not passed up the food chain. It has a moderate acute toxicity to warm-blooded animals and a very low toxicity to fish and other aquatic organisms. Application of the water-based formulations require careful selection of aircraft and specific procedures to achieve an acceptable population reduction (Fellin et al., upublished manuscript, Canada/US Spruce Budworm Program, CANUSA). At the registered dosage rate no lasting unacceptable adverse environmental effects have been observed.

c) Malathion (an organophosphate insecticide). Malathion is a nonpersistent, broad-spectrum insecticide, registered for use against numerous insect pests, and is probably the most widely accepted insecticide. It is less toxic to warm-blooded animals than most other organophosphorus compounds. When applied against the western budworm, previous results have not been consistent and it has not been used since 1976 (Fellin et al., unpublished manuscript, Canada/US Spruce Budworm Program, CANUSA).

d) Mexacarbate (a carbamate insecticide). Mexacarbate was recently re-registered for western budworm control as Zectran^{R} DB. Zectran has a very low dermal toxicity to mammals and is nonpersistent, lasting only a few hours in full sunlight. It also is degraded by biological systems. Zectran is highly toxic to western budworm, especially sixth instars, and can be used in very small amounts (Fellin et al., unpublished manuscript, Canada/US Spruce Budworm Program, CANUSA).

2. Aerial Application of Bacillus thuringiensis (B.t.). This is a naturally occurring aeriobic, spore- and crystal-forming pathogen that affects only insects in the order Lepidoptera. Once ingested, the interaction of digestive juices with the crystals and spores ruptures the gut wall. Feeding ceases within a few hours after ingestion, although affected insects may not die for several days.

The formulations Dipel^{R} and Thuricide^{R} are registered for use against the western budworm. The use of B.t. has been variable because the results of past applications have been erratic and the cost of B.t. has been high compared to chemical insecticides. But the cost of B.t. is now near that of chemical insecticides, and recent tests have shown that B.t. can be effective at higher dosages. B.t. is especially useful in and around sensitive areas and where off-target drift is unacceptable, where other pesticides are restricted, and where no treatment would be the only other alternative (Fellin et al., unpublishehd manuscript, Canada/US Spruce Budworm Program, CANUSA).

C. Biocontrols. Budworms have a number of natural regulating factors -- predators, parasites, weather. Predators such as ants and birds can be important in maintaining low budworm densities, but parasites are usually not a major source of mortality. Unfortunately, the techniques are not available to augment the influence of predators on an outbreak, and there is nothing to be done about the weather. The combined effects of all these natural factors can be responsible for the waning of budworm populations. But the combined effect of natural agents does not prevent or reduce population resurgences when climatic and forest/stand conditions are favorable to the insect.

D. Silvicultural Treatment. Addressing a current insect infestation with silvicultural manipulations is impractical. However, silviculture can be quite useful in the long-term. Greater species diversity could be created by greater use of ponderosa pine in reforestation. Giant sequoia might be adaptable to some northern aspects if growth rates of trees along Highway 3 are any indication. The abundance of heavy infestations in stands with multilayered crown canopies indicates that this condition should be addressed in future management plans in order to reduce stand susceptibility. Even-aged strategies do appear to be particularly effective against budworm, although they may not be best in all stands or under all conditions. Thinnings would be done to remove stressed trees,. improve tree vigor, and maintain species diversity.

E. Combination. Budworm populations in the older infested stands appear to be declining while populations in other stands are increasing. Some control action such as the use of B.t. could be used on the latter stands, while no action or the use of some chemical could be selected for the former stands.

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